

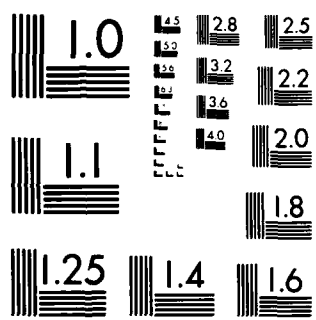
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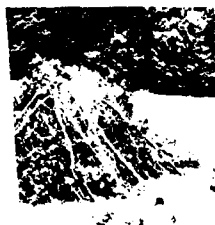
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GREENTREE RESERVOIRS

Section 5.5.3, US ARMY CORPS OF ENGINEERS
WILDLIFE RESOURCES MANAGEMENT MANUAL

by

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Environmental Laboratory

DEPARTMENT OF THE ARMY

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) <p>Guidance for establishing greentree reservoirs is given in Section 5.5.3 of the US Army Corps of Engineers Wildlife Resources Management Manual. The report is designed to provide the Corps District or project biologist with basic instructions for the development, operation, and management of a greentree reservoir. Major topics include wildlife use, site selection, design and construction, and operation and maintenance.</p> <p>Greentree reservoirs are impounded tracts of bottomland hardwood forests that are managed to attract waterfowl. The purposes and objectives for establishing a greentree reservoir are outlined in this report. Although waterfowl are the principal users, other wildlife species that benefit from these flooded timberlands are also discussed. Basic requirements for a reservoir site are described and include terrain, soils, source of waterfowl, vegetation, and water supply. Specifications are given for impoundment design and construction, and guidelines are provided for the successful operation and management of</p> <p>(Continued)</p>					
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19. ABSTRACT (Continued).

a greentree reservoir. Suggestions are offered for the prevention of impacts caused by improper drainage or prolonged flooding of bottomland hardwood forests. . .

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PREFACE

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This report was prepared by Dr. Wilma A. Mitchell and Mr. Charles J. Newling, Wetlands and Terrestrial Habitat Group (WTHG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Mr. Chester O. Martin, Team Leader, Wildlife Resources Team, WTHG, was principal investigator for the work unit. Individuals who contributed information to this report were Mr. Steven L. Duzan, USDA Forest Service, Delta National Forest, Rolling Fork, Miss.; Mr. George T. Heard III, USDA Soil Conservation Service, Vicksburg; and Messrs. Tommy D. Wardlaw and John T. Knight, US Army Engineer District, Vicksburg. Review and comments were provided by Mr. Martin and Mr. Charles V. Klimas, WTHG, and Dr. Kenneth Reinecke and Mr. Don Delnicki, US Fish and Wildlife Service, Vicksburg Field Station, Patuxent Wildlife Research Center.

The report was prepared under the general supervision of Dr. Hanley K. Smith, Chief, WTHG, EL; Dr. Conrad J. Kirby, Chief, Environmental Resources Division, EL; and Dr. John Harrison, EL. Dr. Roger Saucier, WES, was Program Manager, EIRP. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division (PGAD). Illustrations were prepared by the Engineering Graphics and Cartographic Section, PGAD, under the supervision of Mr. George R. Crist.

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NOTE TO READER

This report is designated as Section 5.5.3 in Chapter 5 -- MANAGEMENT PRACTICES AND TECHNIQUES, Part 5.5 -- WETLAND HABITAT MANAGEMENT, of the US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 5.

GREENTREE RESERVOIRS

Section 5.5.3, US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

<hr/> WILDLIFE USE 4 Waterfowl 4 Other Species. 4 PURPOSE AND OBJECTIVES 5 SITE SELECTION 5 Terrain and Soils 6 Source of Waterfowl. 6 Vegetation 6 Water Supply 7 DESIGN AND CONSTRUCTION 8 Size and Shape 8 Levees 9 Water Control Structures 13	<hr/> Access Roads 15 OPERATION AND MANAGEMENT 15 Plan of Operation 15 Timber Management. 16 Maintenance 17 PERSONNEL AND COSTS. 18 Impoundment Construction 18 Maintenance. 18 CAUTIONS AND LIMITATIONS 19 Vegetational Changes 19 Management Considerations. 20 LITERATURE CITED 21
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Greentree reservoirs are impounded tracts of bottomland hardwood forests that are managed to attract waterfowl. These areas are shallowly flooded during fall and winter to make food (primarily acorns and benthic organisms) and resting/roosting habitat available for wintering ducks. When properly managed, greentree impoundments are flooded after trees become dormant and are drained before the growing season begins, thus maintaining the integrity of forest stands. This concept originated as a means to compensate for the unreliability of fall rains and ensure a sufficient annual supply of waterfowl for hunting (Rudolph and Hunter 1964, Hunter 1978).

Greentree reservoirs were first established in the 1930's near Stuttgart, Arkansas, and designated "greentree" (seasonally flooded stands of living trees) to distinguish them from dead tree (permanently flooded) reservoirs. By the 1950's Arkansas and other states were developing greentree areas as refuges and public hunting grounds, and by 1963 most states in the lower

Mississippi Flyway and several in the Atlantic Flyway had reservoirs in operation. Although used chiefly in southern states, the greentree system is now employed as far north as Illinois and Maryland (Rudolph and Hunter 1964, Hunter 1978).

WILDLIFE USE

Waterfowl

The principal waterfowl attracted to greentree reservoirs are dabbling ducks, which feed in shallow water by tipping their bodies to reach food on the bottom. In the Mississippi Flyway, the mallard (*Anas platyrhynchos*) comprises 75 to 90 percent of ducks in greentree areas, and the wood duck (*Aix sponsa*) is the second most numerous species (Rudolph and Hunter 1964). Black ducks (*Anas rubripes*), green-winged teal (*A. crecca*), American wigeons (*A. americana*), gadwalls (*A. strepera*), shovelers (*A. clypeata*), and hooded mergansers (*Lophodytes cucullatus*) also use these flooded timberlands; pintails (*A. acuta*) and diving ducks, except for ring-necked ducks (*Aythya collaris*), are rare (Hunter 1978). In the Atlantic Flyway the mallard, wood duck, and black duck are major species on greentree impoundments, whereas wood ducks are primary reservoir users in the southern end of this flyway (Rudolph and Hunter 1964).

Other Species

Many species of mammals, birds, reptiles, and amphibians occur in greentree reservoirs. Gradually flooded or shallow reservoirs retain dry ground on which mast is accessible to the wild turkey (*Meleagris gallopavo*), northern bobwhite (*Colinus virginianus*), eastern gray squirrel (*Sciurus carolinensis*), fox squirrel (*Sciurus niger*), and white-tailed deer (*Odocoileus virginianus*) (Rudolph and Hunter 1964, Yoakum et al. 1980). Furbearers, such as raccoon (*Procyon lotor*), mink (*Mustela vison*), muskrat (*Ondatra zibethica*), and beaver (*Castor canadensis*), are also commonly found in greentree impoundments (Yoakum et al. 1980). In a quantitative study, Newling (1981) reported 39 species of birds using a greentree reservoir on the Delta National Forest in Sharkey County, Mississippi; no significant differences were found in bird use of the greentree area and adjacent tracts of naturally flooded bottomland forest.

PURPOSE AND OBJECTIVES

The major purpose for establishing a greentree reservoir will determine basic construction requirements. A reservoir will serve chiefly as a waterfowl refuge or as a hunting area. Although these functions are generally compatible, provisions for hunting necessitate differences in reservoir design and operation, as well as careful planning for hunter management.

Primary waterfowl use is another major consideration. Ducks may be attracted to a greentree reservoir for mast, cover, or both. In natural wetlands food may be the prime attraction, whereas resting cover may be more important in heavily farmed regions with alternate food items such as soybeans or grains. Accurate evaluation of waterfowl use will be helpful in selecting a site, determining flooding regime, and devising hunting policy and regulations.

Careful evaluation of objectives and thorough planning will reduce the potential of future management problems. Greentree reservoir theory appears simple, but correct application is critical for preventing damage to timberlands. Proper management depends upon the primary use of a reservoir, and this use should direct its design and operation.

All agencies responsible for the resources of a greentree area should be involved in developing proposed reservoirs. Certain regulations and restrictions for construction and use of a reservoir may depend upon the land source, ownership, and agency responsible for management. Different groups of personnel will likely implement the major phases of a project (planning and design, construction, and operation); therefore, interagency cooperation should be sought to hasten reservoir development and effect management. Agencies that may be involved in developing greentree systems are the U.S. Army Corps of Engineers, the USDA Forest Service, the U.S. Fish and Wildlife Service, the USDA Soil Conservation Service (SCS), and state conservation agencies.

SITE SELECTION

Basic requirements for a reservoir site are proper terrain and soils, a source of ducks, mast-producing hardwoods adapted to flooding, and a sufficient controllable water supply (Hall 1962, Rudolph and Hunter 1964, Yoakum et al. 1980).

Terrain and Soils

Suitable terrain is flat to gently sloping, and ideal soils are predominantly clay. If soils are too porous, water levels cannot be maintained and the area will lose its attractiveness to ducks (Hunter 1978).

Source of Waterfowl

Hall (1962) recommended locating greentree reservoirs near a source of ducks, such as a refuge, lake, or large river. However, isolated wooded tracts should not be disregarded, as isolation may be a positive asset for attracting migrating ducks to an area with little wetland habitat or to an area which has been considered of minor importance to waterfowl (Hall 1962). After construction in 1955 of a 500-acre greentree reservoir on the Noxubee National Wildlife Refuge (NWR) in north-central Mississippi, duck use doubled during the first season; it then increased fivefold with the development of a similar reservoir 3 years later (Rudolph and Hunter 1964). Greentree impoundments may also be beneficial where extensive wetland habitat has been converted to farmland. In these areas mallards and wood ducks frequently feed in agricultural fields and move into nearby greentree reservoirs to roost.

Vegetation

Greentree systems are managed for high-quality mast-producing trees, chiefly bottomland oaks (Fig. 1). Major species utilized by waterfowl are pin oak (*Quercus palustris*), water oak (*Q. nigra*), willow oak (*Q. phellos*), Nuttall oak (*Q. nuttallii*), cherrybark oak (*Q. falcata* var. *pagodaefolia*), Shumard oak (*Q. shumardii*), and swamp chestnut oak (*Q. michauxii*) (Hall 1962, Rudolph and Hunter 1964, USDA Forest Service 1969). Studies of oak mast utilization suggest variations in preferences among waterfowl species in different geographical regions (Hall 1962, Allen 1980).

Most greentree reservoirs are composed of mixed hardwood species. Mast producers such as blackgum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), and bald cypress (*Taxodium distichum*) may be valuable to waterfowl in years of poor acorn production (Rudolph and Hunter 1964). See the Cautions and Limitations section for a discussion of potential effects of dormant-season flooding on bottomland hardwood communities.



Figure 1. Bottomland hardwood vegetation typical of a greentree reservoir

Water Supply

A greentree impoundment should be constructed near a dependable water supply that can be regulated for flooding and dewatering at the proper times. Major sources of water are streams, rivers, lakes, storage reservoirs, irrigation projects, wells, and rainfall. The source should not be a system of running water subject to frequent overflow (Hall 1962), as heavy layers of silt can cause loss of entire timber stands (Broadfoot and Williston 1973, Hunter 1978) and endanger levees. Swift currents and increased water depths are inconsistent with safe hunting and may cause ducks to evacuate an area for more accessible feeding and resting sites (Hall 1962).

Impoundment of rainfall is the most economical method of flooding greentree reservoirs in regions which have reliable fall precipitation (Yoakum et al. 1980). However, the most effective methods do not depend upon seasonal rainfall but allow complete control of water levels. Excellent water regulation can be obtained by diverting a permanent stream into the reservoir. This method is adaptable where low-gradient streams, not exceeding 1 ft/mile, enter

terraces and well-drained bottomlands; a flashboard or gate-type structure placed in the streambed can channel inflowing water into the impoundment and permit removal of water as necessary (Rudolph and Hunter 1964, USDA Forest Service 1969). A body of water, such as a lake or storage reservoir, at a higher elevation than the greentree site may provide a dependable water supply that can be effectively controlled; this method employs gravity flow to deliver water and control structures to regulate it (Rudolph and Hunter 1964, Hunter 1978). Pumping from wells, streams, rivers, or lakes affords complete control of flooding, but annual operational costs may be prohibitive for large acreages. In rice-producing regions, water may be available from irrigation projects (Rudolph and Hunter 1964, Hunter 1978); however, possible herbicide and pesticide problems should be investigated before considering these sources for greentree areas.

DESIGN AND CONSTRUCTION

Technical engineering guidance and planning are required for all proposed greentree reservoirs. SCS will provide specifications for impoundment construction without charge to private landowners and State and Federal agencies. SCS offices maintain aerial photographs and corresponding soil survey maps which identify the soil types and drainage systems of all land within each county. This information, combined with that obtained from a traverse survey, should be sufficient for developing specifications related to drainage and soil factors such as site location and levee dimensions. A detailed plan should be made that includes location and design of levees, diversion channels, dams, spillways, and water control structures. Major considerations in designing the levee system and placing control structures are to avoid flooding adjacent lands and to ensure rapid, complete drainage of the reservoir at the critical period before trees break dormancy.

Size and Shape

Factors that influence appropriate size include site capability and availability, feasibility of operation, and expected hunting pressure. Although habitat availability may limit reservoir size, noncontiguous bottomlands may be developed into small greentree impoundments. Some areas, such as the Noxubee NWR, support several reservoirs of a few hundred acres that were constructed successively in response to increasing waterfowl use and hunting

pressure. Size is not a criterion for developing an area that will attract large numbers of waterfowl (Rudolph and Hunter 1964, Hunter 1978). Near Stuttgart, Arkansas, 50,000 mallards have been found on less than 200 acres of flooded bottomlands (Hunter 1978); reservoirs of 100 to 600 acres may contain large duck populations.

Potential hunting pressure will likely be the most important determinant of reservoir size. Hall (1962) recommended more than 200 acres for hunted reservoirs; however, those with nonrestricted public hunting should include at least 1500 acres. Impoundments of this magnitude can safely support greater numbers of hunters than can smaller ones, and quality of the waterfowl hunting experience generally increases with decreasing hunter density. Size will not be so critical for a reservoir with restrictions on legal hunting hours and number of hunters.

Other factors that influence size of hunted reservoirs are an adequate supply of ducks, good access, and sufficient personnel to enforce regulations. As ducks show differential use of space within a reservoir and move in response to shooting pressure, a large amount of greentree area will be needed to regularly accommodate successful hunting. A large reservoir should have good access roads with parking areas or permit water transportation to remote sections; if these criteria cannot be met, several smaller reservoirs would be preferable to 1 large reservoir. The total size of greentree area under active management will depend upon the personnel available for operation and maintenance; it is not advisable to flood more land than can be effectively managed during hunting season or properly maintained during drawdown.

Greentree reservoirs have no standard configuration. Boundaries usually follow land contours, and higher elevations are incorporated as natural levees whenever possible. Impoundments on the Delta National Forest illustrate a variety of shapes (Fig. 2).

Levees

Land elevation should be used as much as possible to provide natural levees, thus promoting drainage and reducing construction and maintenance costs. However, at least 1 dike per reservoir will be necessary, and levees may be required to enclose an entire reservoir located on uniformly flat terrain.

Levee design. Appropriate levee height depends upon terrain. A levee 2 to 3 ft high is sufficient on flat land, but higher levees will be required

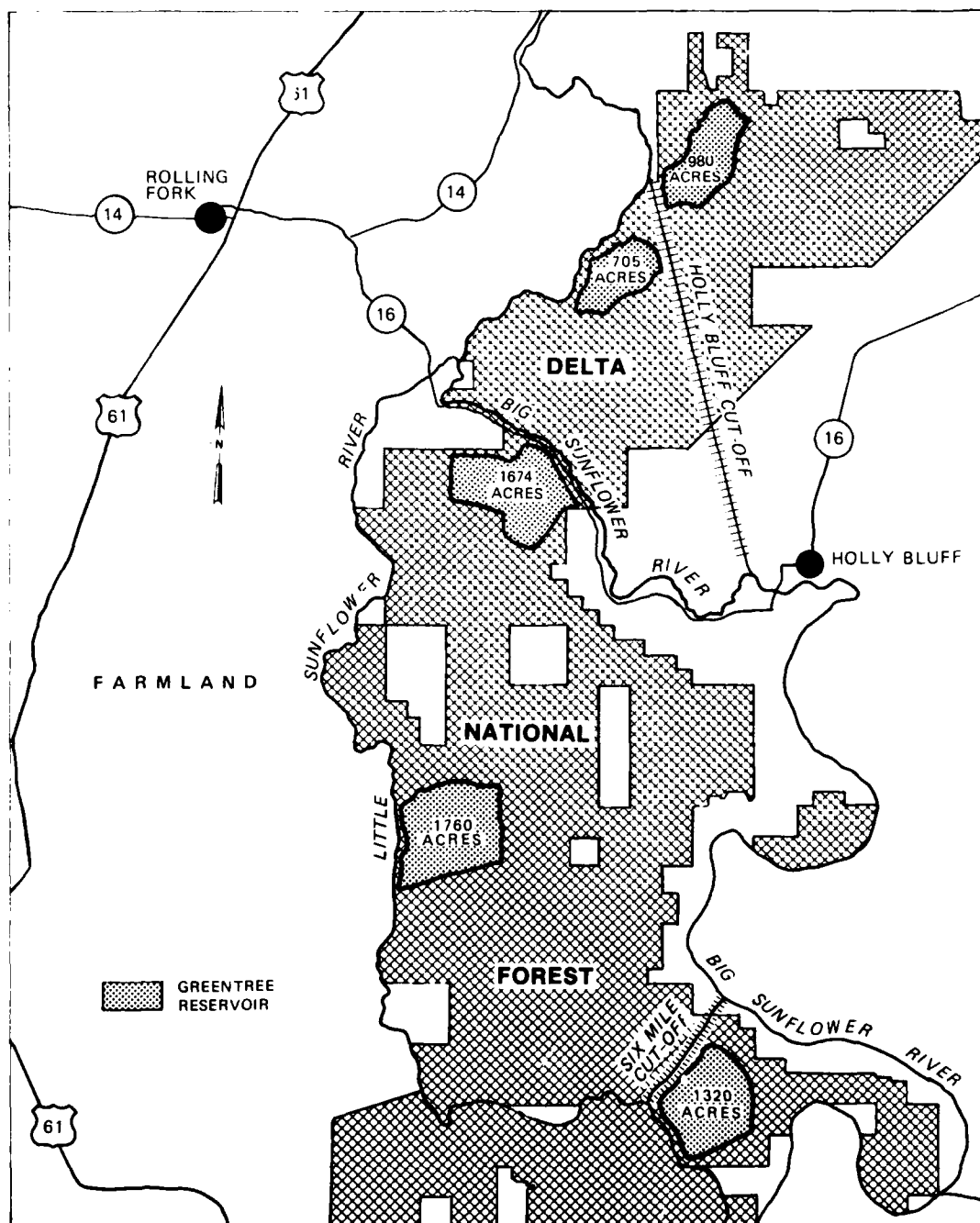


Figure 2. Schematic diagram of the greentree reservoir system on the Delta National Forest, Mississippi

for sites with irregular topography containing potentially deep-water areas. An average height of 4 ft can be expected on a typical greentree site. Levee grades should be established to provide 2 to 3 ft of freeboard above the ponding elevation (USDA Forest Service 1969) (Fig. 3).

The levee crown should be at least 4 ft wide to allow for small vehicle traffic (Yoakum et al. 1980), but wider levees will more easily accommodate vehicles needed for mowing and other maintenance. A minimum crown width of 10 ft is recommended for most greentree levees.

Yoakum et al. (1980) recommended that levees have a 3 to 1 slope downstream and a 4 to 1 slope upstream. Unless the region is subject to natural flooding, these dimensions should provide sufficient stability for the low levees characteristic of most greentree systems. However, the SCS (1976) recommends a 3 to 1 slope on both sides, because such levees are more tolerant to flood damage yet can still be easily maintained.

Borrow areas. Borrow areas for levee construction should be located outside the impoundment site (Yoakum et al. 1980). Soil removal from the reservoir creates a deep-water hazard for hunters and may require construction of bridges for access. An ideal location for earth removal is the high ground where a spillway will be constructed; if properly located, the borrow area may

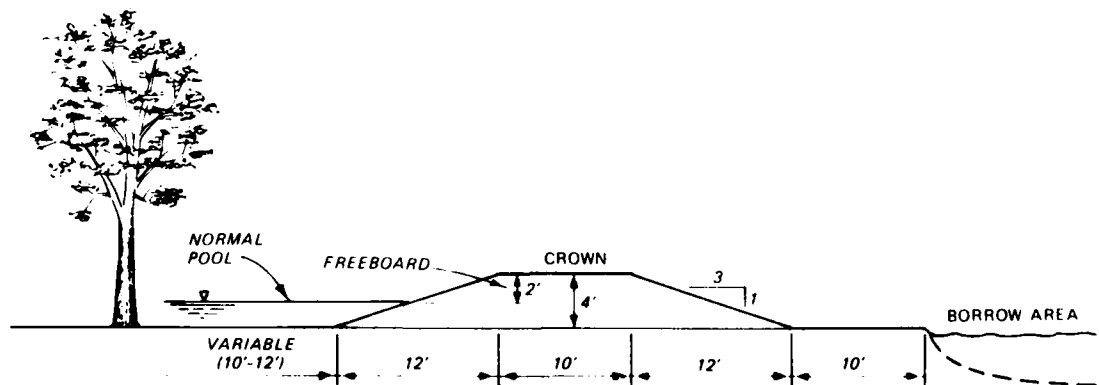


Figure 3. Recommended levee dimensions for a greentree reservoir

be incorporated into the spillway (Yoakum et al. 1980). To provide stability for a levee less than 6 ft high, a berm at least 10 ft wide should be located between the dike and borrow area (SCS 1976).

Rights-of-way. Maximum levee right-of-way may depend upon other resource uses of the land on which a reservoir will be located; for example, management for timber production may limit rights-of-way to a minimum width. No specific width is needed for clearance inside the impoundment except that necessary for levee maintenance. Outside the reservoir, the berm and borrow area will require at least 20 to 25 ft beyond the toe of the levee but may extend further if there are no restrictions on land use.

Turfing. Erosion is best controlled by establishing vegetative cover on the entire levee system (Fig. 4); gravel should be used on top of levees only where heavy-duty vehicles will be needed for special service. Levees should be seeded with herbaceous species, preferably legumes or grasses, over an area extending several feet beyond the toe on both sides of the levee. Soil type and establishment time of various species are primary considerations in selecting the best cover. The SCS can recommend the most well-adapted species and provide appropriate planting guides.



Figure 4. Greentree reservoir levee covered with vegetation (courtesy USDA Forest Service)

Perennial warm-season grasses that establish rapidly and form dense cover are best to use for embankment stabilization, especially in areas subject to natural flooding. Grasses such as bermuda (*Cynodon dactylon*) or dallis grass (*Paspalum dilatatum*) can be overseeded with legumes to provide winter cover that may also serve as supplemental food for wildlife. White clover (*Trifolium repens*) and cool-season grasses such as ryegrass (*Lolium* spp.) are heavily utilized by deer; wheat (*Triticum aestivum*) is a good attractant for wild turkey during nesting and brood-rearing. This vegetation is especially beneficial during high-water periods, providing accessible food in flooded bottomlands. However, the amount of acreage planted for wildlife should be limited and carefully planned, as poaching may become a problem on long segments of levee covered with preferred wildlife foods. Vegetation planted to attract wildlife should be located on the portions of the levee with least accessibility to game violators.

Water Control Structures

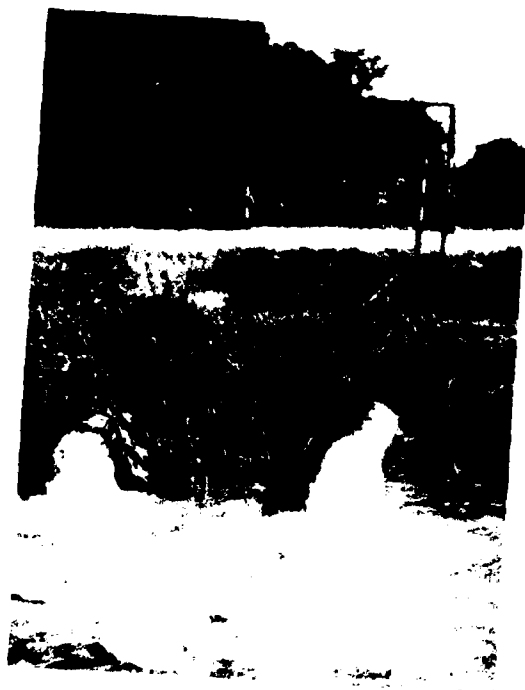
The design, size, and number of control structures will depend upon characteristics of the watershed. Placement of outlet structures is determined chiefly by watershed drainage, and natural flow patterns should be retained as much as possible. Strategic location of outlet structures is necessary for complete drainage in regions subject to periodic inundation. Therefore, natural outflow patterns should be carefully studied to determine structure placement that will maximize drainage potential yet protect the surrounding habitat.

Radial gates and flashboard risers (stop logs) are the most efficient water control structures (Hunter 1978) and may be used to regulate both inflow and outflow. Stop logs are planks inserted horizontally between grooved recesses in concrete supporting piers; logs may be placed and removed manually or by a chain hoist operated from a frame constructed above the logs (Fig. 5). A flashboard structure may also be made by placing risers in one-half of a culvert set into a concrete base and connected to a metal pipe or culvert that passes through the levee.

The major outlet structure may be made of corrugated metal pipe that passes beneath the levee to the reservoir pool or to a set of stop logs (Fig. 6a). Minor outlet structures may be placed in the ends of culverts and controlled with flapgates or screw valves (Fig. 6b); valves should be located



Figure 5. Stop log water control structure (courtesy USDA Forest Service)



a. Primary outlet structure passing beneath levee



b. Minor outlet structure controlled with screw valve

Figure 6. Standard outlet structures used on greentree reservoirs (courtesy USDA Forest Service)

so they will be accessible at all times, even under natural flooding conditions. Hunter (1978) recommended an automatic overflow control system capable of regulating predictable surplus water and compensating for failure of manually operated devices.

To dispose of peak flows, emergency spillways may be required. A spillway can be incorporated into a levee but must be stabilized with soil, concrete, or paving material; water should flow over the spillway onto undisturbed earth (Yoakum et al. 1980).

Access Roads

An all-weather access road must be provided from an existing road to a greentree reservoir. It should be wide enough to allow the passing of two 4-wheel-drive trucks and must be maintained during winter months. Except for maintenance vehicles, dikes should be kept free of traffic by placing vehicular control gates at points of access to the levees. Parking areas large enough to accommodate public use should be located near the entrance to the reservoir.

OPERATION AND MANAGEMENT

Plan of Operation

Depth. Optimum feeding depth for dabbling ducks is 6 to 18 in.; the ground need not be completely inundated, as ducks will use the low dry ridges for loafing sites (Rudolph and Hunter 1964, Yoakum et al. 1980). Mast is not readily available in deeper water; therefore, average depth over the reservoir should be 12 to 18 in. with maximum depth under 3 ft. These depths also afford safe accessibility for a hunter in chest waders. Average depths exceeding 18 in. may be considered if hunter access by boat is permitted and is a greater priority than waterfowl food or access by foot.

Water level control. Flooding should be started early enough in the fall to attract migrating waterfowl. It can be initiated with leaf color change, which indicates the beginning of dormancy, and will generally require 6 to 8 weeks for completion. Water must be removed in late winter or early spring before onset of the growing season. Thorough drainage is essential; only a few inches of water or saturated ground during the growing season can cause

permanent timber damage within 1 to 2 seasons (Hunter 1978). Hall (1962) recommended that water retention not exceed 4-1/2 months on greentree reservoirs in the Southeast. The period of safe flooding is from early October to late February in the South but may extend from late September to mid-April in more northern states (Rudolph and Hunter 1964, Atlantic Flyway Council 1972, Yoakum et al. 1980).

Water levels can be manipulated to effect maximum utilization of the mast crop. For example, on areas with serious competition from other wildlife species, premature depletion of mast may be prevented by filling reservoirs in early fall and periodically lowering the water level as duck use increases (Rudolph and Hunter 1964). However, a reservoir that has heavy fall waterfowl concentrations can be flooded gradually to prevent early acorn depletion by ducks (Hunter 1978). On large reservoirs that contain excessive depths, water levels can also be increased in stages, thus making available mast which might otherwise be too deep for dabbling ducks; in both cases ducks are attracted to the feather-edge of slowly rising water (Hunter 1978).

If pumping will provide the source of water, steps should be taken during the planning phase to ensure that the system will be operative for the designated season of initial use. The correct pumps must be ordered in sufficient time for delivery and installation so that timing of flooding will be consistent with pump capacity. Otherwise, users may have to rely upon rainfall to fill the reservoir, a source that may not be adequate.

Timber Management

Annual dormant-season flooding of timber over the long term may cause increased soil moisture and a shift of the forest community toward vegetation characteristic of wetter habitats (Newling 1981). If such a community shift is undesirable and if a greentree system contains several reservoirs, a rotation scheme can be devised to alternate reservoir use. At least 1 impoundment may remain unflooded each winter to permit thorough drying and soil aeration and thus promote continued regeneration of typical bottomland hardwood species.

Under a 100-year rotation, 70% of the timber on a greentree reservoir can be retained in mast production. Depending upon the total acreage of the reservoir, regeneration cuts may range from 1 to 15 acres. The larger cuts are preferred for commercial profit, as there is no market in some areas for

hardwood timber under 14 in. in diameter at breast height (dbh). Size of cuts will also vary according to the quantity of mature timber available for removal at the time of cutting. Adequate time for regeneration should be allowed by conducting all cuts prior to the spring growing season. Intermediate cuts may be made in 20- and 30-year-old stands and should result in a residual stand of 60 to 70 sq ft of basal area; this density produces crown development conducive to volume growth and increased mast production (USDA Forest Service 1969).

Maintenance

Inspection. Regular inspection of greentree reservoirs is an essential management requirement. The purposes of fall and winter inspections are chiefly to check the operation of water control structures and to regulate water inflow to the reservoir. In spring, impoundments must be inspected frequently to ensure complete drainage and minimize interference by beavers. Beaver obstructions impede drainage, and ponding may result in serious timber damage within a single season (Rudolph and Hunter 1964). In areas of heavy beaver activity, inspection could be required 2 or 3 times per week during drawdown. Debris must be promptly removed from water control structures, and levees should be inspected for beaver tunnels and signs of erosion. Periodic inspection is also needed during summer, especially after heavy rains.

Levees. Maintenance of greentree reservoir levees requires mowing, bushhogging, reseeding, and fertilization. Bushhogging is periodically needed to control invading woody species, and levees should be mowed just before hunting season to permit access. A levee system may contain acreage equaling as much as 5 to 10 percent of the area within the reservoir. On a 1000-acre impoundment, maintenance could be needed for 100 levee acres; therefore, a rotation scheme would be feasible for maintaining vegetation on extensive levee systems. The greentree management plan for the Delta National Forest suggests fertilizing levee vegetation approximately every 3 years and reseeding or overseeding at 4- to 6-year intervals. Reseeding should not leave soil vulnerable to erosion; overseeding, as practiced for pasture renovation, would be preferable to disking and replanting.

PERSONNEL AND COSTS

Impoundment Construction

Major considerations regarding the cost of impoundment construction are mobilization and demobilization of equipment, clearing and grubbing, levee embankment, turfing, water control structures and pumps (if required), access roads, and vehicular control gates. Total costs will vary among greentree systems and among reservoirs within a system. For a greentree system of 5 reservoirs to be constructed in the Delta National Forest, the costs projected in 1979 for building an impoundment ranged from approximately \$9 to \$17 per linear foot (LF) with an average unit cost of about \$13/LF (USACE 1979).

Unit cost is not only a function of levee length or number of acres impounded. Variations also result from differences in soil and terrain factors that determine levee dimensions and the quantity, size, and placement of water control structures. Control structures may be expected to constitute up to one-fourth of the total impoundment cost. On the Delta National Forest, costs for structures ranged from 10% to 22% of the costs of impoundments constructed by the U.S. Army Engineer District, Vicksburg (USACE 1979). For reservoirs requiring pumps, the pumps and related facilities may equal or exceed the cost for impoundment, and pumping constitutes the major annual cost after construction. Therefore, to ensure a dependable funding source, costs of initial construction and annual pumping should be realistically estimated during the planning phase.

Maintenance

Levees, water control structures, and access roads must be maintained throughout the year. Costs for maintenance should include provisions for the following items: (1) mowing levees 2 times per year; (2) fertilization and reseeding of levee vegetation on a rotational basis; (3) frequent inspection of levees and water control structures during drainage; (4) maintenance of water control structures and pumps, if required; and (5) grading and repair of access roads.

CAUTIONS AND LIMITATIONS

Vegetational Changes

A major concern of greentree management is that prolonged dormant-season or inadvertent growing season flooding can be detrimental to bottomland hardwoods. Although tree mortality has not been reported from correctly managed greentree reservoirs, long-term studies have failed to verify earlier reports of increased acorn production (Minckler and McDermott 1960) and timber growth (Broadfoot 1958, Broadfoot and Williston 1973). Rogers (1981) found that 20-year-dbh growth of trees on flooded plots was approximately equal to that on normal plots in the Mingo Basin of southeastern Missouri, and McQuilkin and Musbach (1977) reported no significant difference between production of pin oak acorns on a greentree reservoir in Missouri and on a natural site.

Some research has shown impacts on bottomland hardwood forests subjected to long-term dormant-season flooding. In a 5-year study on the Delta National Forest, Mississippi, Francis (1980) found strong variation from season to season but an overall decrease in Nuttall oak acorn production on a greentree reservoir compared with a naturally flooded site. Minckler and McDermott (1960), Brakhage (1966), and Thomson and Anderson (1976) reported decreased regeneration of overstory species in forest communities of greentree reservoirs; recent studies have shown a shift to more water-tolerant species such as water hickory (*Carya aquatica*) and overcup oak (*Quercus lyrata*) (Fredrickson 1979, Newling 1981), species that are somewhat less desirable for waterfowl food than oaks producing small acorns. Stress may contribute to insect and disease problems that can ultimately result in tree mortality (McCracken and Solomon 1980, Smith and McGinnes 1982).

Although research has indicated negative aspects of seasonal flooding on some greentree reservoirs, the factors responsible for these results have not been elucidated. In summarizing the impacts of flooding on bottomland hardwood stands, Klimas et al. (1981) stated that dormant-season flooding has not been shown to result in overstory mortality except when the prescribed pre-growing season drawdown did not occur. Correct management of greentree reservoirs should help prevent the development of detrimental effects that could be associated with long-term seasonal flooding.

Management Considerations

Drainage is the critical factor in the proper management of greentree reservoirs; its importance cannot be overemphasized. Water retention during the growth period can kill many mast species within one season (Rudolph and Hunter 1964); therefore, drawdown must be initiated early enough to ensure complete water removal by the time trees break dormancy. Because of the flat terrain and impervious soils characteristic of greentree sites, drainage problems are likely to occur in unusually wet years; increased seasonal rainfall and heavy natural flooding may prevent complete dewatering by early spring and result in soil saturation late into the growing season. Unchecked beaver activity can inhibit good drainage, and water from heavy summer rains may remain longer in some greentree reservoirs than on surrounding natural hardwood bottomland (Newling 1981). These problems can be successfully solved if corrective measures are implemented promptly. Chief management responsibilities are recognition of these and other local impediments to effective water removal and prompt initiation of remedial action.

To provide as much flooded mast-producing timberland as possible may appear to be the ideal goal. However, the amount of greentree area that can be effectively managed will depend upon the availability of personnel, an important consideration that may be overlooked or underestimated when planning greentree reservoirs. Correct management of these impoundments requires sufficient personnel, particularly to monitor areas during drawdown so that potentially hazardous drainage problems can be avoided.

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